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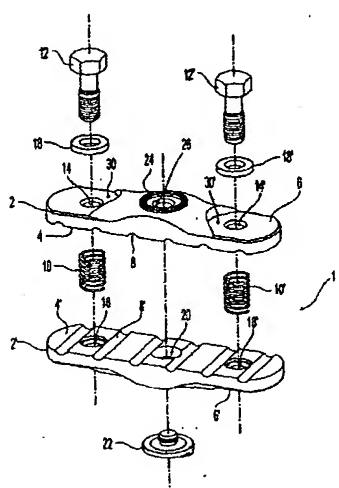

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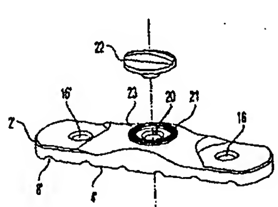

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**(57) Abstract:** A simplified external bone fixator assembly (1) is provided which allows the surgeon to snap a bone fixation rod (100) into the assembly at any location along the length of the rod. The invention does note "threading" of the assembly onto the rod starting at the end and sliding it down the length of the rod to the desired location. In particular, a bone pin locking assembly (1) is provided for use with standard bone fixation rods (100) and bone pins (28). The assembly (1) includes a bone pin vise (2), a single-piece fixation rod attachment member (56, 156, 256) and a coupling (58, 158, 258) to allow relative adjustment of pin vise (2) and rod attachment member (56, 156, 256). The single-piece rod attachmant member (56, 156, 256) has two opposing jaws (83, 82'; 182, 182'; 282, 282') that loosely capture the bone fixation rod (100) when the surgeon presses the rod into the attachment member (56, 156, 256). The assembly (1) may be rigidly fixed to the rod (100) using a bolt (92) which tightens the attachment member (56, 156, 256) onto the rod (100).

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# MULTI-PIN CLAMP AND ROD ATTACHMENT

## TECHNICAL FIELD

The present invention relates to a traumatologic device, and, more particularly, to an improved traumatologic device for reducing long-bone fractures that require external fixation.

## BACKGROUND OF THE INVENTION

A variety of traumatologic devices for reduction of bone segments are known in the art. For example external bone fixation devices (commonly referred to as external fixators) are known. Typically external fixators are used to reduce fractures of the long bones in the human body. These devices are placed in position under anesthesia. In order to reduce the duration of the anesthesia, fixator devices have been developed to allow positioning at every possible angle, while still allowing easy adjustment by a surgeon.

Devices designed to the present day generally fix the bone pin clamp to the bone fixation rod by way of a closed hole and screw combination, or by using two-piece open face bone fixation rod jaws which by their nature cannot be self-sprung and so require the use of an additional piece or pieces, such as a coil or compression spring, to maintain the jaws in an open position during installation onto the bone fixation rod. The two piece nature of such designs increases unit fabrication difficulty and cost.

Accordingly, there is a need in the art to provide a simpler bone pin clamp assembly that makes it easier for an operator to engage the clamp assemblies and bone fixation rod, while still providing maximum flexibility to the operator in adjusting the distance between bone pin clamps on either side of a fracture.

## SUMMARY OF THE INVENTION

The present invention provides a device for coupling a bone pin locking assembly to a bone fixation rod. In one embodiment the device comprises: a fixation rod clamp having a rod attachment member with a longitudinal axis, a jaw portion having first and second opposing jaws configured to receive the fixation rod, and a coupling portion; a coupling having a pin vise cooperating portion to engage

the bone pin locking assembly and configured to receive the coupling portion of the rod attachment member. The rod attachment member may be a single piece, and the jaw portion of the rod attachment member may engage the bone fixation rod when the bone fixation rod is pressed into the opposing jaws, thereby coupling the bone pin locking assembly to the bone fixation rod.

The fixation rod clamp first opposing jaw may further have a first spring constant, and the second opposing jaw may have a second spring constant, so that when the jaws are displaced from a rest position, resulting spring forces are generated in the jaws which force the jaws back to the rest position. The fixation rod clamp first opposing jaw may have an associated spring arm with a first spring constant, and the second opposing jaw may have an associated spring arm with a second spring constant, so that when the jaws are displaced from a rest position, resulting spring forces are generated in the spring arms which force the jaws back to the rest position. Each fixation rod clamp spring arm also may have a wall, and each wall may have an inner and an outer surface, with at least one surface having a cutout. Alternatively, both spring arm inner surfaces may have cutouts, or both spring arm outer surfaces may have cutouts. Where more than one surface has a cutout, the cutouts may be of equivalent size and shape, or they may be of different size and/or different shape. The geometry of the cutouts may be arcuate, triangular, square or stepped.

The pin vise cooperating portion of the coupling may further have a bearing face incorporating serrations configured to engage cooperating serrations in the bone pin locking assembly, where the serrations are configured upon engagement to prevent relative movement between the coupling and the bone pin locking assembly. The coupling may further have a spring and a bore, where the spring is at least partially accepted within the bore and compressed between the pin vise cooperating portion of the coupling and the bone pin locking assembly. This spring may tend to separate the coupling and the bone pin locking assembly to allow free relative rotational movement of the two during operation.

The fixation rod clamp rod attachment member first and second opposing jaws may further have a clearance therebetween which is sufficient to provide an interference between the opposing jaws and the bone fixation rod when the fixation rod is inserted into the fixation rod clamp jaw portion.

The spring constants associated with the rod attachment member first and second opposing jaws may be equal, or they may be unequal. The fixation rod may further be configured so that when the bone fixation rod is pressed into the rod attachment member the first and second spring arms, and their associated opposing jaws, are displaced from their rest position an unequal amount. The fixation rod may also be configured so that upon pressing the bone fixation rod into the rod attachment member the first spring arm and its associated jaw is displaced from its rest position, and the second spring arm and its associated jaw remain substantially stationary.

The fixation rod clamp may further be configured to have a locked position which substantially prevents movement of the clamp along the bone fixation rod. The clamp may also comprise a bolt disposed within and operatively associated with the clamp jaw portion, such that tightening of the bolt configures the assembly to the locked position.

The fixation rod clamp may further be configured so that the jaw portion engages the bone fixation rod when the rod is pressed into the fixation rod clamp in a direction substantially along the longitudinal axis of the rod attachment member.

The fixation rod clamp coupling may further be configured to provide rotation of the single piece rod attachment member about a first axis substantially perpendicular to the longitudinal axis of the bone pin locking assembly, and also to provide rotation of the single piece rod attachment member about the rod attachment member longitudinal axis, where the rod attachment member longitudinal axis is substantially perpendicular to the first axis.

An external fixator may also be provided for coupling bone pins to a bone fixation rod, and comprising a bone pin locking assembly having first and second engaging faces for engaging the bone pins, and a fixation rod member having any of the previously identified attributes, wherein the coupling is configured to permit rotation of the single piece rod attachment member about a first axis substantially perpendicular to the bone pin locking assembly engaging faces, and also to permit rotation of the single-piece rod attachment member about the rod attachment member longitudinal axis, the rod attachment member longitudinal axis being substantially perpendicular to the first axis.

An external fixator comprising all of the above attributes may also have pin vise portion engaging faces comprising grooves, and the engaging faces may further be coupled with one or more threaded fasteners, and the pin vise portion may be configured to permit engaging the bone pins through contact with the grooves upon tightening the one or more threaded fasteners.

## BRIEF DESCRIPTION OF THE DRAWINGS

The features and advantages of the present invention will become more readily apparent from the following detailed description of the invention in which like elements are labeled similarly and in which:

FIGS. 1a and 1b are exploded perspective views of a bone pin vise portion, and a bone pin vise opposing plate and star grind cover, respectively, of the bone pin locking assembly of the current invention;

FIG. 2 is an exploded perspective view of a fixation rod clamp of the bone pin locking assembly of the current invention;

FIG. 3 is a perspective view of an assembled bone pin vise portion of FIG. 1 connected to an assembled fixation rod clamp of FIG. 2;

FIGS. 4a, 4b and 4c are exploded perspective views of three embodiments of a rod attachment member;

FIGS. 5a, 5b and 5c are cross-sectional views of the embodiments of a rod attachment member of FIGS. 4a, 4b and 4c, and a bone fixation rod;

FIG. 6 is a perspective view of a one embodiment of a complete bone fixation device installed on a bone; and

FIG. 7 is a perspective view of an embodiment of the stacked clamp assembly of the present invention.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The traumatological device of the present invention is discussed herein with reference to a preferred embodiment adapted to be used in the consolidation and fixation of a fractured long bone. It is to be understood that the invention finds applicability for use in any circumstance in which it is desired to fix the orientation of bone segments on either side of a fracture.

Referring more particularly to the drawings, FIG. 1a shows an exploded view of a bone pin vise portion. As shown in FIG. 1a, the bone pin vise portion 1 comprises first and second opposing plates 2 and 2' with engaging faces 4 and 4', and outside faces 6 and 6'. Each engaging face is characterized by a plurality of spaced parallel grooves 8 and 8' which are cylindrically arcuate and which are in confronting relation to the spaced parallel grooves on the face of the opposite plate. The parallel grooves 8 and 8' coordinate to receive the proximal ends of bone pins 28 (shown in FIG. 6) installed on one side of a fractured bone. When the pin vise portion is in the clamped condition, the bone pins 28 are nested in the respective grooves formed by the conjunction of parallel grooves 8 and 8' (of engaging faces 4 and 4'). It will be understood that the number and shape of the grooves is not critical to the operation of the device.

The opposing plates 2 and 2' are connected by two vise bolts 12 and 12' which operate to draw together engaging faces 4 and 4' in order to grip the proximal ends of bone pins 28 which have been installed in a bone. Vise bolts 12 and 12' are slideably accepted by corresponding bores 14 and 14' in each end of first opposing plate 2, and are threadably accepted by threaded bores 16 and 16' in each end of second opposing plate 2'. The internal threads of bores 16 and 16' of second opposing plate 2' correspond with the external threads of vise bolts 12 and 12' such that a clockwise rotation of vise bolts 12 and 12' acts to draw opposing plates 2 and 2', and therefore engaging faces 4 and 4', together. Further, first opposing plate 2 incorporates bolt head bearing surfaces 30 and 30' to provide uniform bearing contact with the bottoms of the heads of pin vice bolts 12 and 12'. The vise bolts 12 and 12' may be provided with washers 18 and 18' positioned between the heads of the vice bolts 12 and 12', and bolt head bearing surfaces 30 and 30' of the pin vise portion opposing plate 2. The washers serve to reduce friction between the vise bolts and bolt head bearing surfaces, thereby easing final tightening of the vise bolts.

Preferably, the vise bolts 12 and 12' will be initially fit with the washers 18 and 18', then installed in the opposing plates, followed by a "loose-fit" tightening to the point that only a small clearance remains between the cylindrical voids formed by the plurality of spaced parallel grooves 8 and 8' and the outside surfaces of the cylindrical bone pins 28. In this way the pin vise portion 1 may easily be slipped onto the bone pins 28, such that during the surgical procedure only minor additional tightening of the vise bolts 12 and 12' will be required to firmly fix the bone pins 28 within the bone pin vise portion 1.

In a preferred embodiment, the pin vise portion opposing plates 2 and 2' incorporate coil springs 10 and 10' between engaging faces 4 and 4' to forcibly separate engaging faces 4 and 4'. The provision of this separating force holds the plates apart during installation of the pin vise portion onto the bone pin proximal ends, easing such installation. To this end, cylindrical coil springs 10 and 10' are installed about the shafts of vise bolts 12 and 12' such that vise bolt shafts are slidably received by the bore formed within the inside diameter of each coil spring 10 and 10' (see FIG. 3).

FIG. 2 shows an exploded view of one embodiment of a fixation rod clamp 50, comprising a single-piece rod attachment member 56, a coupling 52, a coil spring 68, and a coupling bolt 64. The single-piece rod attachment member has a cylindrical coupling portion 58 which is slidably disposed within an aperture 54 formed by the body of the coupling 52. Single-piece rod attachment member 56 is thus interconnected to and slidably disposed within the coupling 52 so as to allow 360-degree rotation of the single-piece rod attachment member 56 within the coupling aperture 54. The coupling bolt 64, having a head and a threaded distal end 66, is slidably disposed within a bore 70 formed in the body of coupling 52. The longitudinal axis of bore 70 is oriented perpendicular to that of the coupling aperture 54. The coupling bolt threaded distal end 66 is threadably accepted by an internally and compatibly threaded bore 26 formed in the top center of opposing plate 2 (shown in FIG. 1a) of pin vise portion 1 (shown in FIG. 1a). The single-piece rod attachment member 56 is interconnected to and rotatably disposed, with two degrees of rotational freedom, about pin vise portion 1, and about bone pins 28 (shown in FIG. 6). The first degree of rotational freedom is provided by the rotation of single-piece rod attachment member 56 relative to the fixation rod clamp

coupling 52; the second degree of rotational freedom is provided by the rotation of the fixation rod clamp coupling relative to pin vise portion 1.

The single-piece rod attachment member 56 is stabilized and fixed to the fixation rod clamp coupling 52 by tightening the coupling bolt 64. Tightening of the coupling bolt 64 also results in the stabilization and fixation of the entire fixation rod clamp 50 to the pin vise portion 1.

In a preferred embodiment, the coupling 52 has a bearing face 60 incorporating serrations 62 which extend over the entire face, and which correspond with like serrations 24 (shown in FIG. 1a) formed in the corresponding bearing face of the pin vise portion 1. The serrations may be disposed in a radial fashion to form a "star grind," or may have any type of profile known in the art. The serrations 62, 24 serve to minimize or prevent rotational slippage between the coupling 52 and the pin vise portion 1 subsequent to final tightening of the coupling bolt 64.

In another preferred embodiment, the pin vise portion opposing plate 2' (shown in FIG. 1b) incorporates an internally threaded bore 20, into which the coupling bolt 64 of a second fixation rod clamp 50 (shown in FIG. 2) may be threaded. The bearing face 21 of the pin vise portion opposing plate 2' incorporates serrations 23 which extend over the entire face, and which correspond with like serrations 62 of the bearing face 60 of a second fixation rod clamp 50 (shown in FIG. 2). The serrations 62, 23 serve to minimize or prevent rotational slippage between the second coupling 52 and the pin vise portion 1 subsequent to final tightening of the second coupling bolt 64. Two fixation rod clamps 50 may thereby be installed on one pin vise portion 1 to provide the fracture site with the additional stabilizing force of a second bone fixation rod 100 (shown in FIG. 7). For those instances in which the surgeon does not require the additional stabilizing force of a second bone fixation rod, an externally threaded "star grind" cover 22 (shown in FIGS. 1a and 1b) is provided. The cover is threadably accepted by the internally threaded bore 20 of the pin vise portion opposing plate 2' (shown in FIGS. 1a and 1b).

As shown in FIG. 2, the coupling bolt 64 may be provided with a coil spring 68 disposed about the circumference of the bolt 64. The spring is partially slidably received within a bore 71 provided in the coupling bearing face 60. This bore is of larger diameter than coupling bore 70, which results in the creation of a circumferential ledge 72 within the coupling 52. When compressed between the

coupling circumferential ledge 72 and the pin vise portion 1 (shown in FIG. 1a), the spring 68 acts to provide a force tending to separate the coupling 52 and the pin vise portion 1. This force prevents engagement of the serrations 62, 24 during installation, and thus enables easy relative rotation and fit-up.

FIG. 4a shows the details of one embodiment of the novel single-piece rod attachment member 56 of the present invention. The single-piece rod attachment member comprises a jaw portion 80, which further comprises a set of opposing jaws 82 and 82', each associated with a respective spring arm 86 and 86'. The spring arms converge to a smooth cylindrical coupling portion 58. Significantly, the rod attachment member 56 is manufactured in a single piece, so that when the jaws 82 and 82' are positively displaced with respect to their rest position, a resulting spring force is generated which tends to force the jaws back to the rest position. The jaw portion 80 is preferably manufactured such that the initial clearance "X" between opposing jaws 82 and 82' is slightly smaller than the outside diameter "Y" of the bone fixation rod 100 (shown in FIGS. 5a, 5b and 5c). In this way an interference is established between jaws 82 and 82' and the bone fixation rod 100 when the bone fixation rod is initially installed into the jaw portion 80. Based on the natural spring action of the spring arms 86 and 86' adjoining the jaws 82 and 82' respectively, the relative interference between the jaws and the bone fixation rod enables the bone fixation rod 100 to be snapped into the bone pin locking assembly (comprising pin vise portion 1 and fixation rod clamp 50) by the operator, resulting in the capture of the bone fixation rod 100 within the jaw portion 80. Although not fully stabilized, the spring action of the spring arms is sufficient to maintain a loose coupling of the assembly with the rod. This frees up the hands of the surgeon performing the fixation procedure.

In one embodiment the spring arms 86, 86' each may have an outer surface b, b' and an inner surface d, d', and at least one of the inner surfaces may have a cutout e, e' to reduce the force required to snap the bone fixation rod 100 into the rod attachment member jaw portion 80. The cutout(s) may be arcuate, or may be any other geometric shape appropriate to reduce the thickness of at least one or perhaps both of the spring arms. The cutout(s) may be formed by any acceptable method (*e.g.* machining, forming, casting, etc.). Furthermore, cutouts e, e' may be symmetrical, providing spring arms with essentially equal spring constants, or they may be asymmetrical so as to provide spring arms with different spring constants.

Additionally, the groove defined by the space between inner surfaces d and d' may be centered about the longitudinal axis of the single-piece rod attachment member, providing spring arms with essentially equal spring constants, or it may be offset so as to provide spring arms having different spring constants.

Final stabilization of the bone fixation rod 100 within the jaw portion 80 is accomplished through the use of a bolt 92 placed through the jaw portion spring arms 86 and 86', in combination with a nut 90 (see FIG. 4a). Upon tightening the nut 90 and bolt 92, the spring arms 86 and 86', and most importantly for the purposes of the invention, the adjoining jaws 82 and 82', are drawn together until the bone fixation rod 100 is firmly held between the jaws 82 and 82'. Repeated loosening and tightening of the fixation rod clamp on the bone fixation rod is possible without the need for re-engagement of the rod within the jaw. In this way the surgeon may easily and repeatedly adjust the position of the fixation rod clamp along the bone fixation rod.

An external hexagon 94 may be provided integral to the shoulder of the jaw bolt 92. This external hexagon 94 conforms to an internal hexagonal recess 96 provided within jaw portion spring arm 86. The bolt is thereby rotationally fixed to the jaw portion, such that the surgeon need only focus on threading the nut onto the bolt without having to worry about holding the bolt still.

A washer 88 may be provided between the nut 90 and jaw portion spring arm 86'. This washer can be of any design known in the art satisfactory to prevent galling of the nut and jaw portion spring arm, and to facilitate installation of nut 90 and bolt 92.

FIG. 4b shows the details of another embodiment of the single piece rod attachment member 156 of the present invention. The single piece rod attachment member of this embodiment comprises a jaw portion 180, which further comprises a set of opposing jaws 182 and 182', each associated with a respective spring arm 186 and 186'. The spring arms converge to a smooth cylindrical coupling portion 158. Spring arm 186 incorporates an arcuate cutout "a" which runs across outside surface "b." The cutout forms a trough whose centerline is perpendicular to the longitudinal axis of the rod attachment member 156. The arcuate cutout "a" reduces the wall thickness "c" of spring arm 186 (shown in FIG. 5b), so that thickness "c" is less than the corresponding wall thickness "c'" of spring arm 186'. This reduction in thickness renders the spring constant for spring arm 186 smaller

than the spring constant for spring arm 186', such that when equal force is applied to the jaws 182, 182', such as during initial installation of rod 100 (shown in FIG. 5b), jaw 182 will be displaced an amount significantly greater than jaw 182'. In a further embodiment, spring arm thickness "c" is sufficiently smaller than spring arm thickness "c'" that when equal force is applied to the jaws, such as during initial installation of rod 100 in jaw portion 180, jaw 182 is displaced from its rest position an amount sufficient to accept rod 100 in jaw portion 180. Because of the differing geometries of the spring arms, jaw 182' will be displaced by an amount much less than jaw 182, such that it will effectively remain stationary. This differs from the embodiment described above (shown in FIG. 4a) in which the spring arm geometries are essentially the same, resulting in the displacement of both spring arms by an equal amount. The overall strength of the spring arms 186, 186' may be maintained, or even increased, as compared to the embodiment described above and in FIG. 4a, by increasing the overall cross-section of the spring arms, such as by making the spring arms wider.

FIG. 4c shows the details of a further embodiment of the single piece rod attachment member 256 of the present invention. The single piece rod attachment member of this embodiment comprises a jaw portion 280, which further comprises a set of opposing jaws 282 and 282', each associated with a respective spring arm 286 and 286'. The spring arms converge to a smooth cylindrical coupling portion 258. Spring arms 286, 286' each incorporate an arcuate cutout "a," "a'" which runs across outside surface "b," "b'." Each cutout forms a trough whose centerline is perpendicular to the longitudinal axis of the rod clamp 256. The arcuate cutouts "a," "a'" reduce the wall thickness "c," "c'" of spring arms 286, 286', thereby reducing the corresponding spring constants of the spring arms. The force required to install rod 100 (shown in FIG. 5c) in jaw portion 280 of the rod clamp 256, is therefore reduced as compared to the force required to install the rod on a jaw portion whose spring arms incorporate no such outer surface cutouts (see FIG. 4a) or where only one spring arm has a cutout (see FIG. 4b). Where cutouts a, a' are equal, the operation of this embodiment is similar to that described above in reference to FIG. 4a, as both spring arms 286, 286' will be displaced by an equal amount upon initial installation of the bone fixation rod. As with the embodiment discussed above in reference to FIG. 4b, the overall strength of the spring arms 286, 286' may be maintained, or even increased, as compared to the embodiment

described above in reference to FIG. 4a, again by increasing the overall cross-section of the spring arms such as by making the spring arms wider. Cutouts a, a' may, in an alternate embodiment, be of different size or shape, providing spring arms 286, 286 with unequal spring constants.

It is noted that in addition to the arcuate cutouts "a," "a'" depicted in FIGS. 4b and 4c, numerous other configurations may be employed to produce spring arms which flex varying amounts during installation of the fixation rod 100, for example, providing spring arms having different geometric shapes and/or widths, spring arms incorporating stepped thicknesses, or combinations of single or multiple interior or exterior cutouts.

FIG. 7 shows a "stacked" bone pin locking assembly which comprises one pin vise portion 1 with two associated fixation rod clamps 50. Such a stacked assembly permits the surgeon to provide an additional stabilizing force, connected to a second bone fixation rod 100, to the fracture site. In this way a framework of bone fixation rods may be built about the fracture site.

Accordingly, it should be understood that the embodiments disclosed herein are merely illustrative of the principles of the invention. Various other modifications may be made by those skilled in the art which will embody the principles of the invention and fall within the spirit and the scope thereof.

## THE CLAIMS

What is claimed is:

1. A fixation rod clamp for coupling a bone pin locking assembly to a bone fixation rod, the clamp comprising:

a rod attachment member having a longitudinal axis, a jaw portion having first and second opposing jaws configured to receive the bone fixation rod, and a coupling portion; and

a coupling having a pin vise cooperating portion to engage the bone pin locking assembly and configured to receive the coupling portion of the rod attachment member,

wherein the rod attachment member comprises a single piece, and the jaw portion of the rod attachment member is configured to engage the bone fixation rod when the bone fixation rod is pressed into the opposing jaws to thereby mechanically couple the bone pin locking assembly to the bone fixation rod.

2. The fixation rod clamp of Claim 1 wherein the first opposing jaw has a first spring constant, and the second opposing jaw has a second spring constant, wherein when the first and second opposing jaws are positively displaced from a rest position, resulting spring forces are generated in the first and second jaws which force the first and second opposing jaws back to the rest position.

3. The fixation rod clamp of Claims 1 or 2 wherein the first opposing jaw is associated with a first spring arm having a first wall and a first spring constant, and the second opposing jaw is associated with a second spring arm having a second wall and a second spring constant, and wherein when the first and second opposing jaws are positively displaced from a rest position, resulting spring forces are generated in the first and second spring arms which force the first and second opposing jaws back to the rest position.

4. The fixation rod clamp of Claim 3 wherein the first wall has an outer surface and an inner surface, and the second wall has an outer surface and an inner surface, and wherein at least one surface comprises a cutout.

5. The fixation rod clamp of Claims 3 or 4 wherein the first wall has an outer surface and an inner surface and the second wall has an outer surface and an inner surface, and wherein both inner surfaces comprise cutouts.

6. The fixation rod clamp of Claims 4 or 5 wherein the at least one cutout comprises a shape selected from the of group of arcuate, triangular, stepped and square.

7. The fixation rod clamp of Claims 2, 3, 4, 5 or 6 wherein the first and second spring constants are equal.

8. The fixation rod clamp of Claims 2, 3, 4, 5 or 6 wherein the first and second spring constants are unequal.

9. The fixation rod clamp of any of the preceding Claims 1 - 8 wherein the pin vise cooperating portion of the coupling comprises a bearing face incorporating serrations configured to cooperatively engage serrations in the bone pin locking assembly, the serrations configured upon their engagement to prevent relative rotational movement between the coupling and the bone pin locking assembly.

10. The fixation rod clamp of any of the preceding Claims 1 - 9 wherein the coupling further comprises a spring and a bore, wherein the spring is at least partially accepted within the bore and compressed between the pin vise cooperating portion of the coupling and the bone pin locking assembly, and provides a force tending to separate the coupling and the bone pin locking assembly to allow free relative rotational movement during operation.

11. The fixation rod clamp of any one of Claims 3 - 10 wherein when the bone fixation rod is pressed into the rod attachment member the first and second spring arms are positively displaced an unequal amount.

12. The fixation rod clamp of any one of Claims 3 - 11 wherein when the bone fixation rod is pressed Into the rod attachment member the first spring arm is displaced and the second spring arm remains substantially stationary.

13. The fixation rod clamp of any one of the preceding Claims 1 - 12 wherein the first and second opposing jaws have a clearance therebetween which is sufficient to provide an interference between the opposing jaws and the bone fixation rod when the bone fixation rod is pressed into the fixation rod clamp jaw portion.

14. The fixation rod clamp of any one of the preceding Claims 1 - 13 wherein the clamp is configured to have a locked position which substantially prevents movement of the clamp along the bone fixation rod.

15. The fixation rod clamp of any one of the preceding Claims 1 - 14 further comprising a bolt disposed within and operatively associated with the fixation rod clamp jaw portion, wherein tightening of the bolt configures the assembly to the locked position.

16. The fixation rod clamp of any one of the preceding Claims 1 - 15 wherein the jaw portion engages the bone fixation rod when the bone fixation rod is pressed into the fixation rod clamp in a direction substantially along the longitudinal axis of the rod attachment member.

17. The fixation rod clamp of any one of the preceding Claims 1 - 16 wherein the coupling is configured to provide (i) rotation of the single piece rod attachment member about a first axis substantially perpendicular to the longitudinal axis of the bone pin locking assembly, and (ii) rotation of the single piece rod attachment member about the rod attachment member longitudinal axis, the rod attachment member longitudinal axis being substantially perpendicular to the first axis.

18. An external fixator for coupling bone pins to a bone fixation rod comprising:

a bone pin locking assembly comprising first and second engaging faces for engaging the bone pins; and

the fixation rod member of any one of the preceding Claims 1 - 17;
wherein the coupling is configured to permit: (i) rotation of the single-piece fixation rod clamp about a first axis substantially perpendicular to the bone pin locking assembly engaging faces, and (ii) rotation of the single-piece fixation rod clamp about the rod attachment member longitudinal axis, the rod attachment member longitudinal axis being substantially perpendicular to the first axis.

19. The external fixator of Claim 18, wherein the pin vise portion first and second engaging faces comprise grooves, and wherein the engaging faces are coupled with at least one threaded fastener, and wherein the pin vise portion is configured to permit engaging the bone pins through contact with the grooves of the first and second engaging faces upon tightening of the at least one threaded fastener.

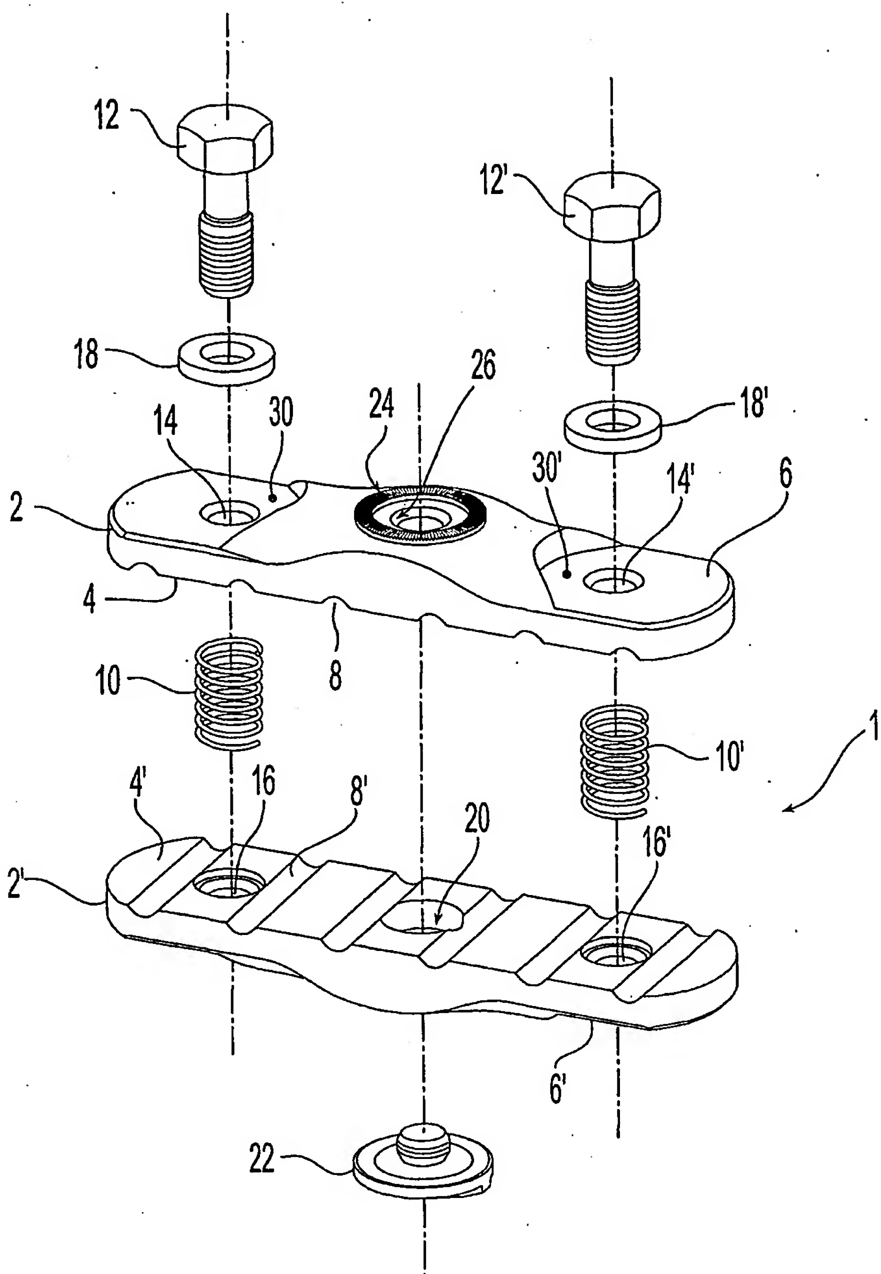


*Fig. 1a*

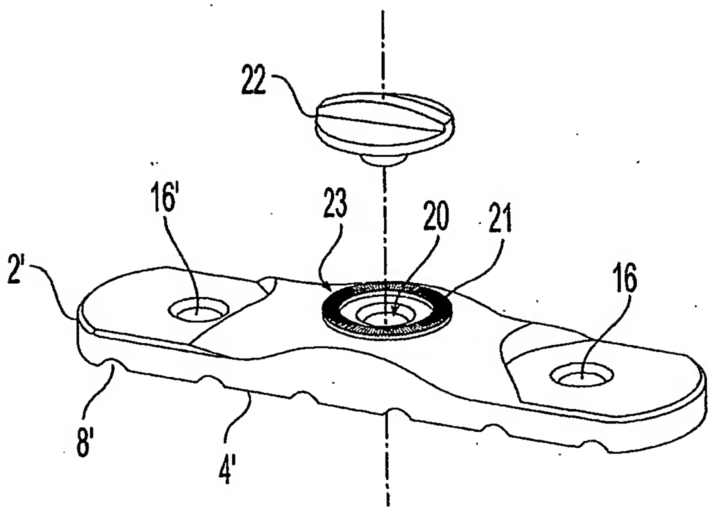


*Fig. 1b*

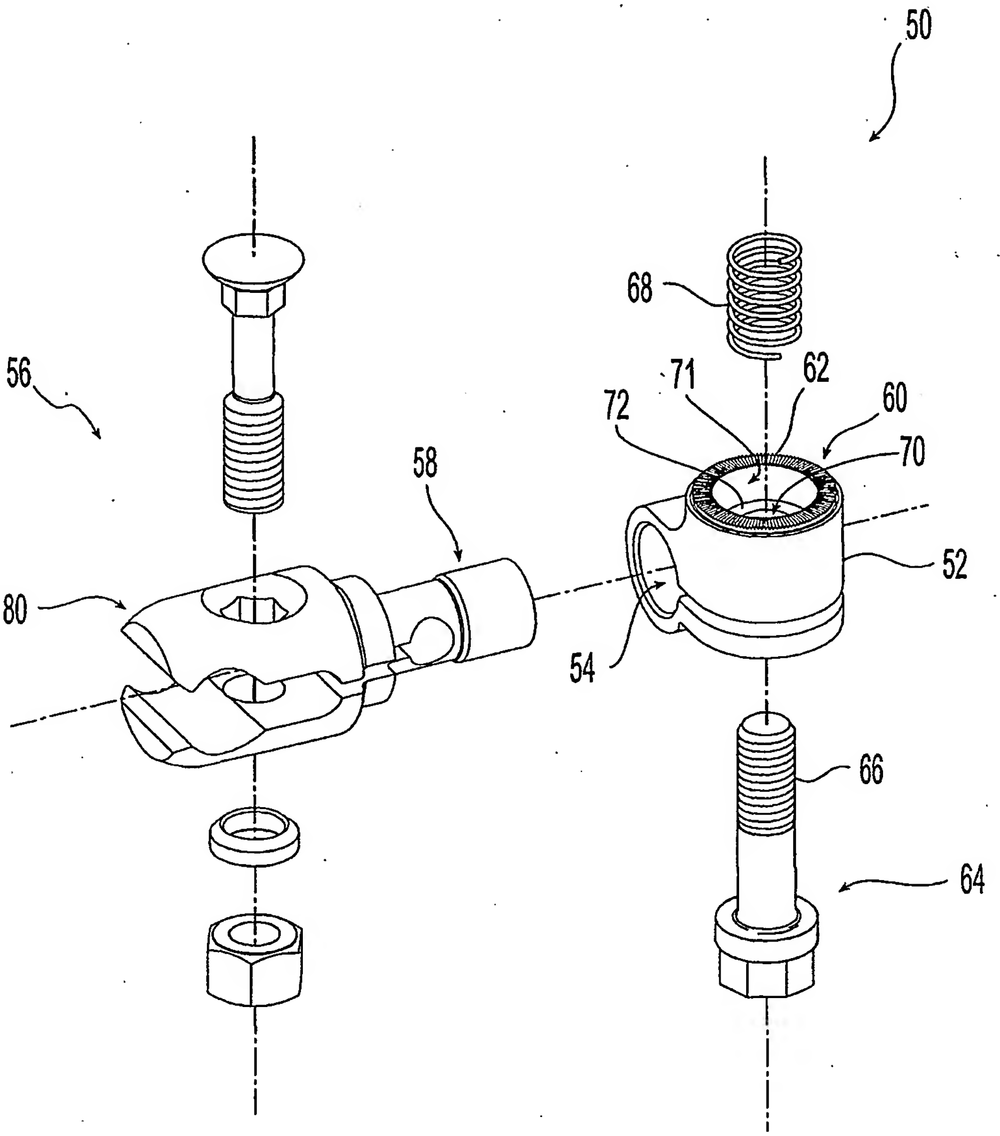


Fig. 2

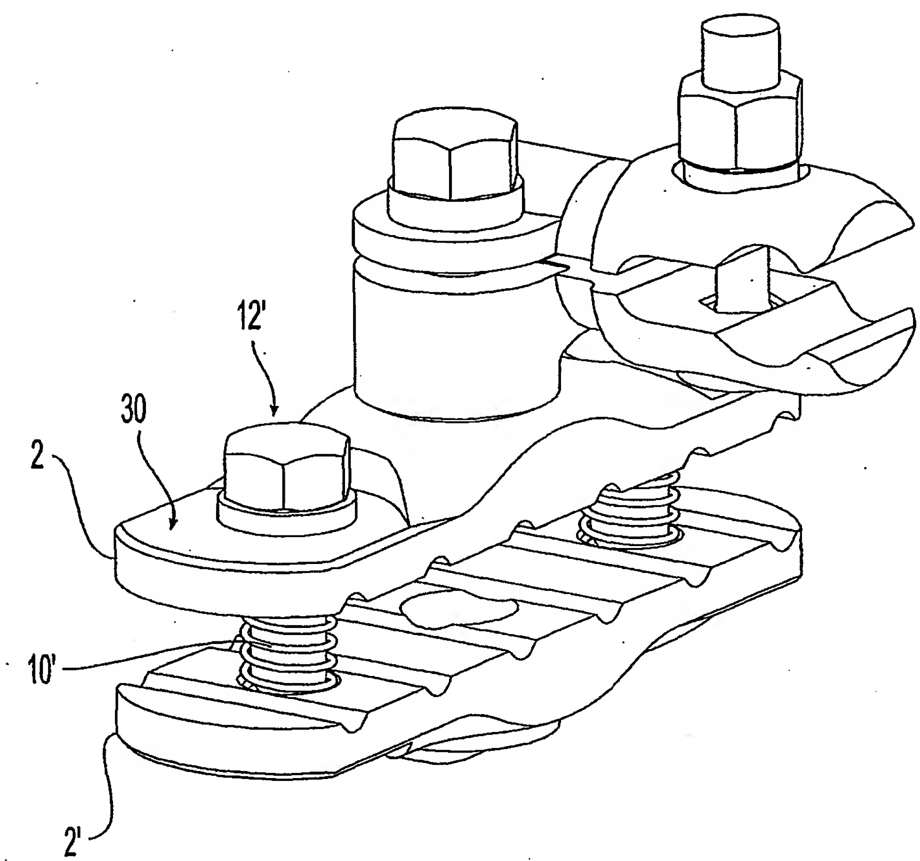


*Fig. 3*

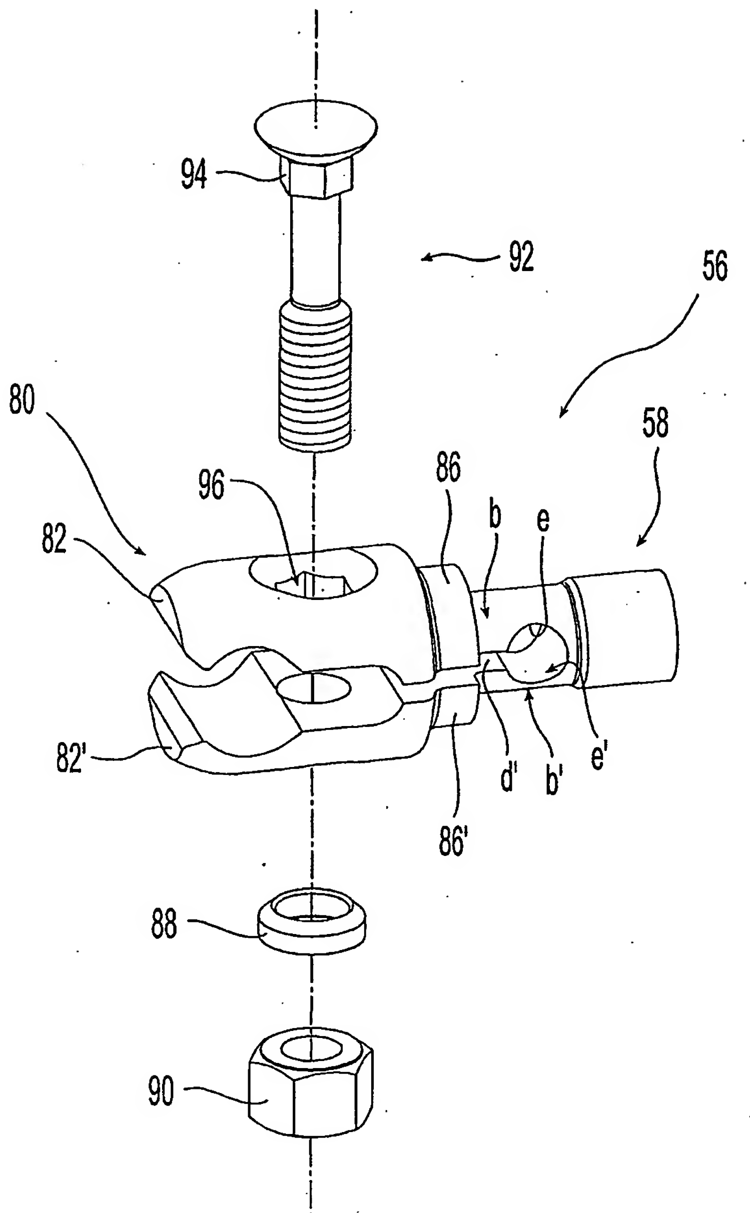


*Fig. 4a*

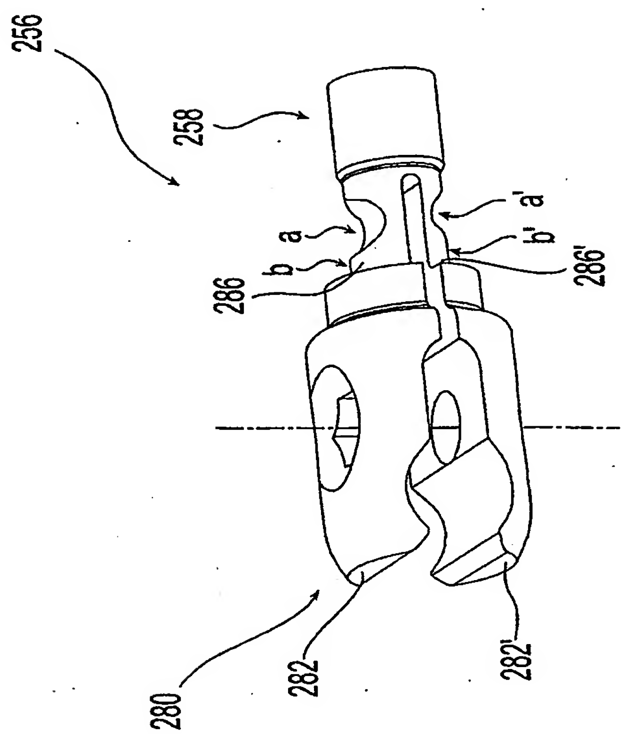


*Fig. 4c*

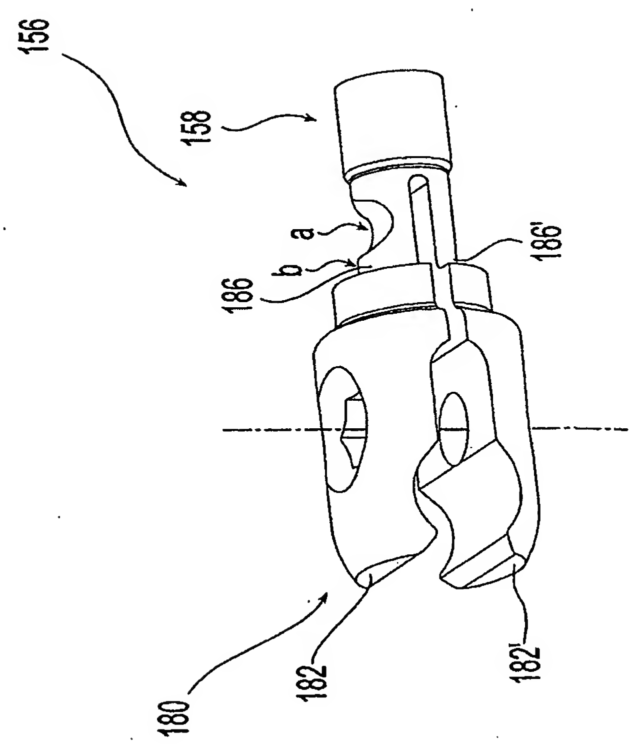


*Fig. 4b*

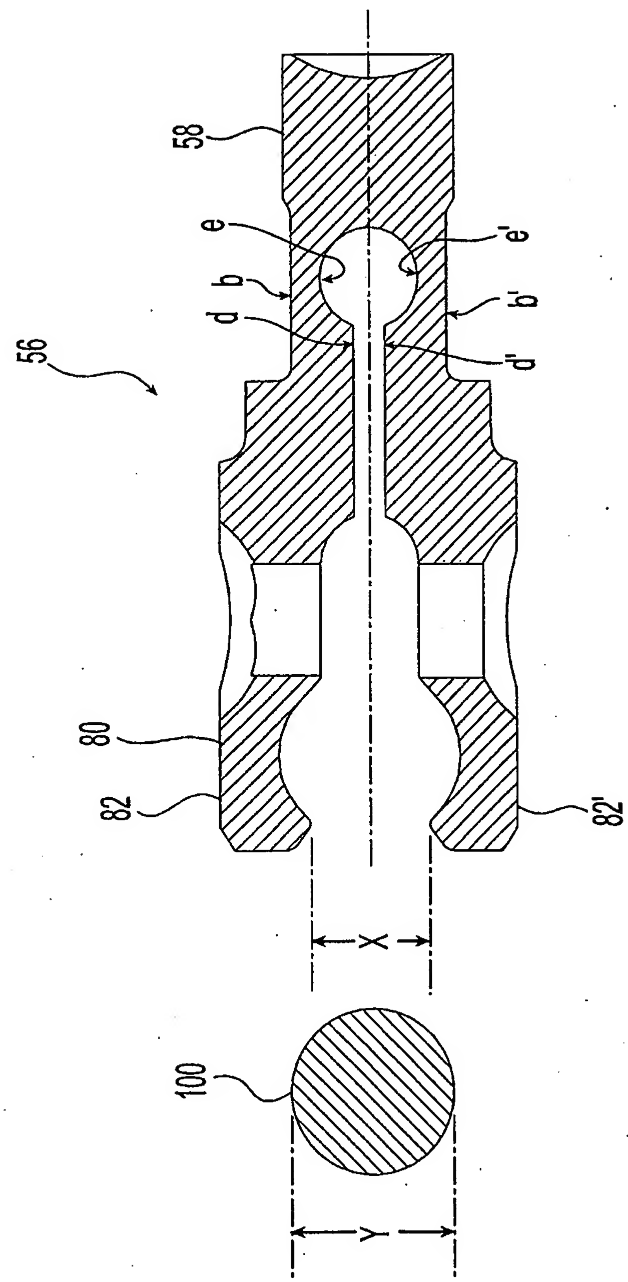


Fig. 5a

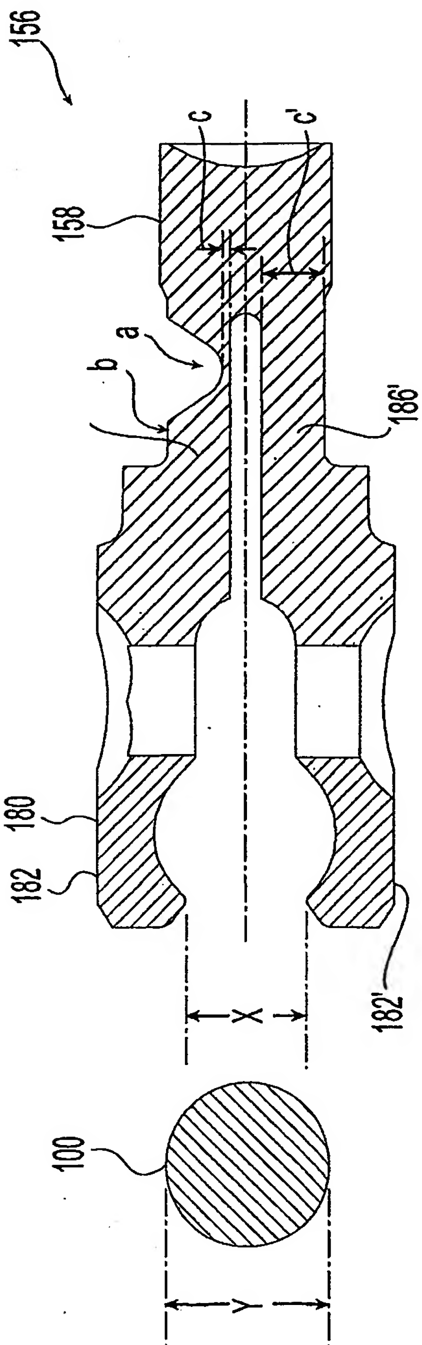
156
158
c
c'
a
b
186'
180
182
182'
X
100
Y

Fig. 5b

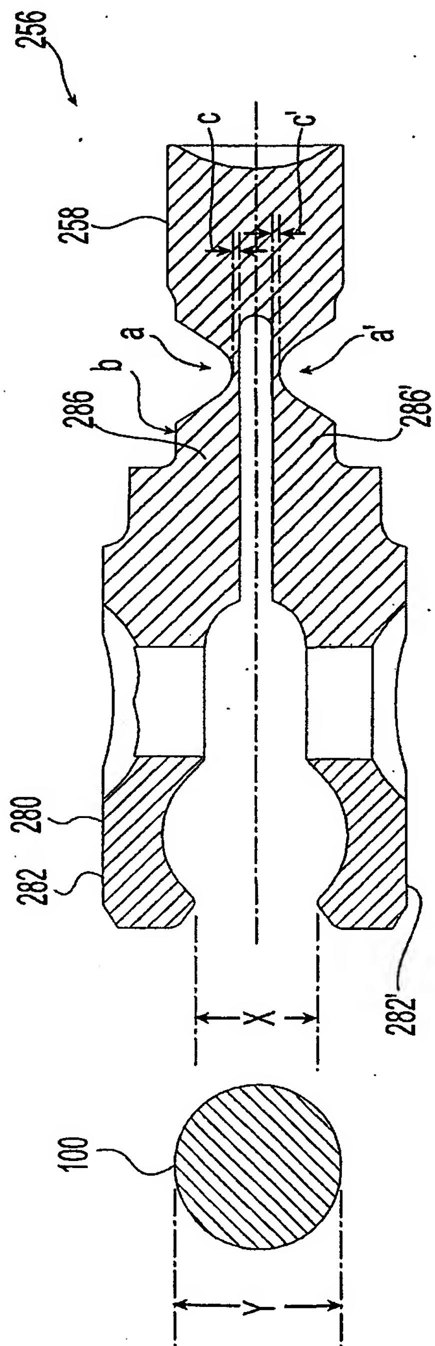
256
258
c
c'
a
a'
b
286
286'
280
282
282'
X
100
Y

Fig. 5c

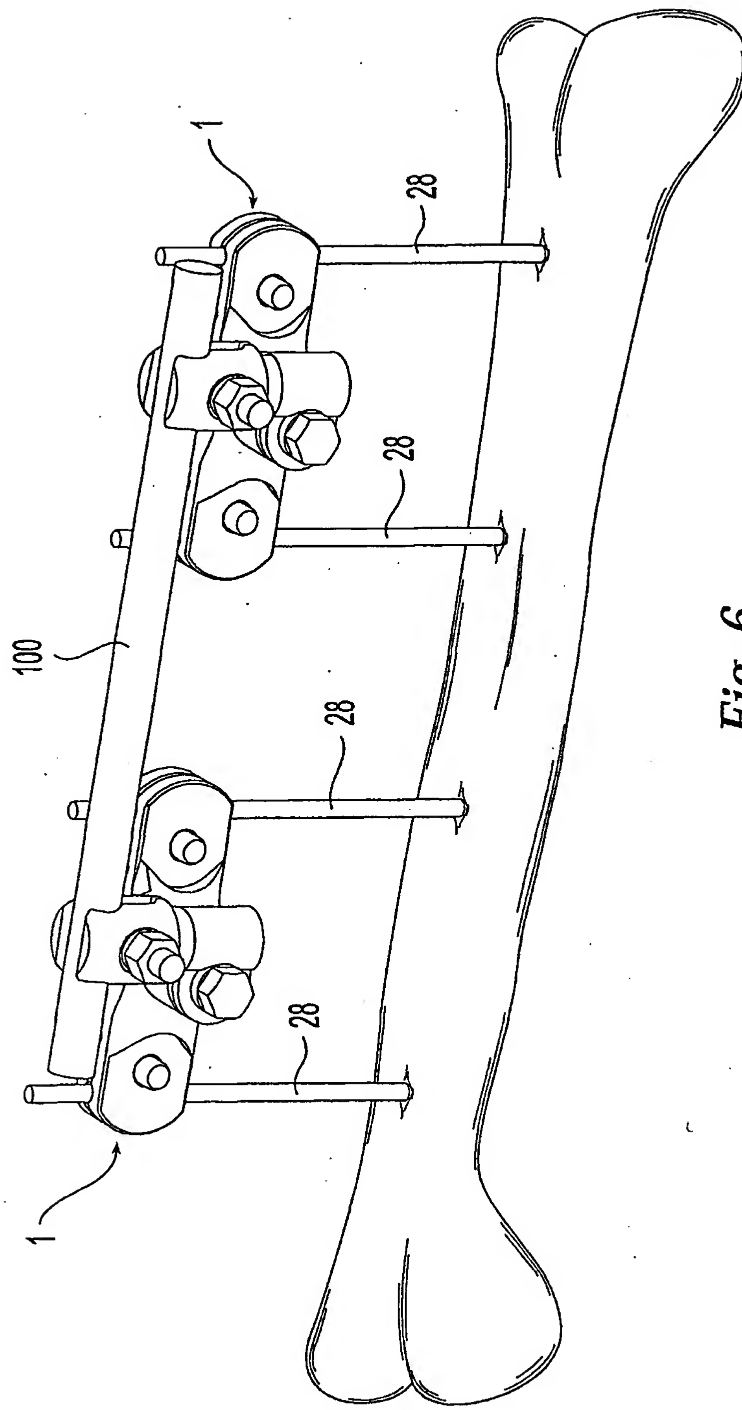


Fig. 6

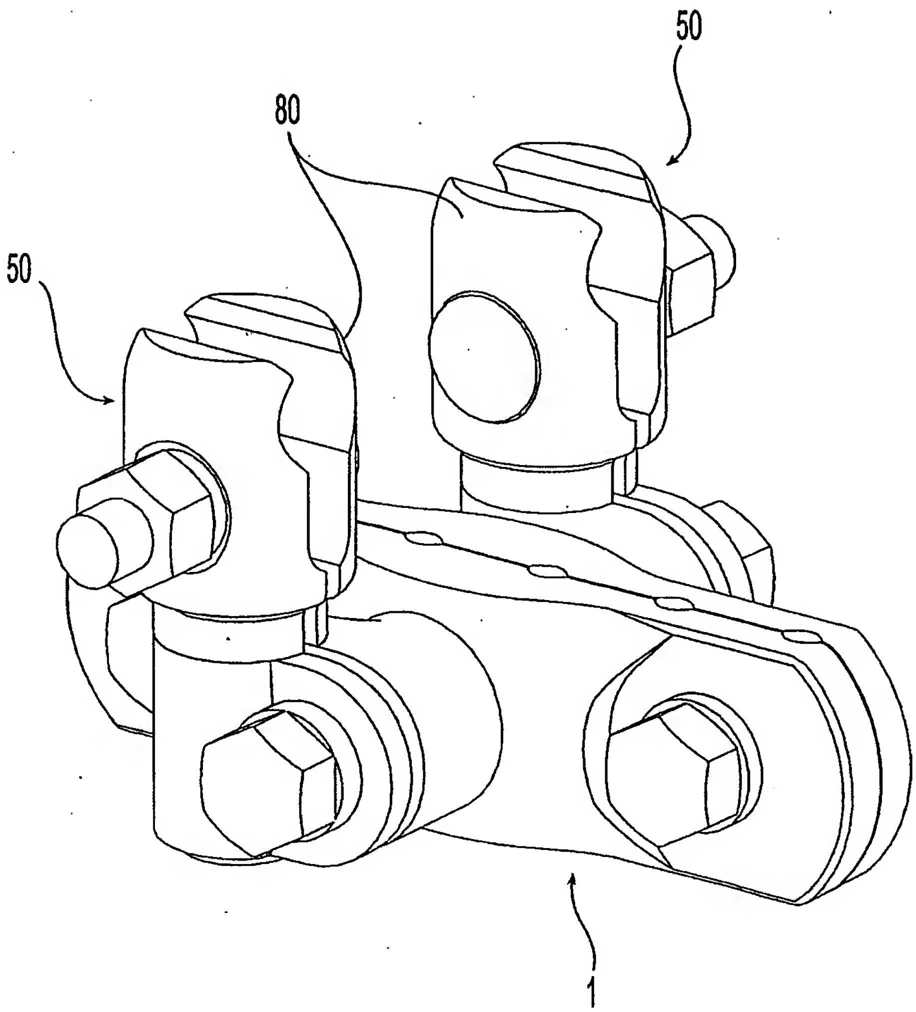


*Fig. 7*